TECHNICAL MEMORANDUM – MASS LOADING ANALYSIS

DATE: **14 July 2012**

TO: **Sunnyside Gold Corporation**

FROM: Mark J. Logsdon (Geochimica) Mark J. Logsdon 14 July 2012

SUBJECT: **MASS LOADING ANALYSIS OF THE UPPER ANIMAS RIVER AT WATER QUALITY STATION A72: CONTRIBUTION OF SUB-BASIN DRAINAGES TO TOTAL LOADING (AND CONCENTRATIONS)**

SUMMARY

This Memorandum evaluates the contributions of the three major sub-drainages reporting to the upper Animas at A72 and the contributions from the major adits (American Tunnel, Gold King, Mogul, and Red& Bonita) to water quality at CC48 (monitoring Cement Creek) and A72 (monitoring all of the upper Animas drainage above Silverton). A particular focus was placed on Zinc because of its conservative properties over the pH range expected to be observed in the upper Animas River Basin. In addition, water-treatment approaches that would be effective for Zinc also would be effective for other pH-sensitive trace metals

The analysis uses mass-balance modeling, based on data for flows and dissolved metals concentrations from Calendar year 2010. The analysis accounts for flows and metal loading in the three major sub-drainages, upper Animas River (at Station A68), Cement Creek (Station CC48), and Mineral Creek (Station M34) as well as four major discharging adits in upper Cement Creek (American Tunnel, Gold King, Red and Bonita, and Mogul).

Under Low Flow conditions, each of the three sub-basins contributes about 1/3 of the total flow observed at Station A72. However, under High Flow conditions, the percentage contribution of Cement Creek (CC48) falls to 9% of total flow at A72 due to the limited surface area of the Cement Creek sub-drainage compared to the total drainage area of A72.

Under Low to Moderate Flow conditions, the four discharging adits contributed 31% to 38% of the total Zinc that reports to Station A72 in 2010. This indicates that control of Zinc currently being released from the four adits is very important to being able to achieve significant reductions in load (and therefore concentrations) at Station A72 under the flow conditions expected over most of the year. Under High Flow conditions (June 2010), the four discharging adits contribute approximately 14% of the total Zinc observed at Station A72. The relatively modest contribution under High Flow conditions suggests that, were active water treatment implemented for the four adits, it may be possible to use a design basis flow that is well below the observed High Flow values, because the residual Zinc in bypass water would make only a small to modest contribution at Station A72.

BACKGROUND

The Animas River Stakeholders Group (Stakeholders Group), of which Sunnyside Gold Corporation (SGC) is an active member, has determined that Water Quality Station A72 is an appropriate location at which to evaluate water-quality conditions in the upper basin of the Animas River.

Station A72 is located in the main stem of Animas River below the town of Silverton, Colorado (Attachment 1). There are three major tributaries contributing to flows at A72:

- The upper Animas River above Silverton. This tributary drains the northeastern portion of the basin above Station A72 and is monitored at Water Quality Station A68.
- Cement Creek. This tributary drains the north-central portion of the upper basin. It is monitored near its mouth with the Animas River at Water Quality Station CC48.
- Mineral Creek. This tributary drains the northwestern segment of the upper basin and is monitored at Water Quality Station M34.

All three drainages have known sources of mining-affected waters, and all three also include flows that have not been affected by mining (Mast et al, 2007).

Station A72 is located approximately 1 mile (1.5 km) below the mouth of Mineral Creek and the water at this point is a physically well-mixed flow of the entire upper basin above Silverton.

Geochimica has reviewed various compilations of water quality data for A68, CC48, M34 and A72 and worked to standardize these data into analyzable sets. For example, mixed reporting units (mg/L and also ug/l), different levels of detection, and default symbols are presented in some versions of data sets. These needed to be standardized in order to do subsequent analyses of water quality in an analytical framework.

In February, 2012, SGC asked Geochimica to evaluate the relative impacts of the three primary tributaries to water quality at A72 and further to specifically evaluate the contribution of the drainage from the four major adits [American Tunnel, Gold King, Red and Bonita, and Mogul] in upper Cement Creek on water quality at downstream stations CC48 and A72. The purpose of the latter task is to understand how control of the flows and chemistries (ultimately as loads) discharging from those adits might affect observable downstream water quality at CC48 and A72.

PURPOSE AND OBJECTIVES

This Memorandum evaluates the contributions of the three major sub-drainages reporting to the upper Animas at A72 and the contributions from the major adits (American Tunnel, Gold King, Mogul, and Red& Bonita) to water quality at CC48 (monitoring Cement Creek) and A72 (monitoring all of the upper Animas drainage above Silverton). A particular focus was placed on Zinc because of its conservative properties over the pH range expected to be

observed in the upper Animas River Basin. In addition, water-treatment approaches that would be effective for Zinc also would be effective for other pH-sensitive trace metals

The specific questions addressed in this Memorandum are:

1. In what proportions do the three subdrainages contribute to stream flows observed at A72?
2. In what proportions do the major discharging adits in upper Cement Creek contribute to the metal loads and concentrations at CC48?
3. In what proportions do the major discharging adits in upper Cement Creek contribute to the metal loads and concentrations observed at A72?
4. What are the uncertainties in the loading analysis at this time?

TERMS OF REFERENCE

The input data was provided to Geochimica by SGC; these data have been developed over time by various entities, working through the Stakeholder Group. The data used in this analysis are in the public domain, and were provided by the Stakeholder Group and the various governmental agencies that have collected the data or presented data provided to them by others.

UNITS, ACRONYMS, INITIALISMS, AND MATHEMATICAL AND CHEMICAL SYMBOLS

In order of use in the memorandum:

L:	liter, a volume unit for fluid
s:	second
/ :	the operator symbol for division
L/s:	liters per second, a modified SI unit of water flow
mg:	milligram, a unit of mass
mg/L:	milligrams per liter, a unit of mass concentration
***** :	the operator symbol for multiplication
mg/s:	milligrams per second, a unit of mass flux or mass loading
%:	percent
Q :	Flow of water
cfs:	cubic feet per second an Imperial unit of water flow
pH:	the negative logarithm of the activity of hydrogen ion in aqueous solution
s.u.:	standard units (for pH measurements)
Al:	Aluminum
Cd:	Cadmium
Cu:	Copper
Fe:	Iron
Mn:	Manganese
Pb:	Lead
Zn:	Zinc
kg:	kilogram, a unit of mass
d:	day
kg/d:	kilogram per day, an informal SI based unit of mass flux or mass loading
RPD:	relative percent difference, a measure of reproducibility between two repeated values. RPD = [(Value 1 – Value 2)/(Value 1 + Value 2)] * 100
Median:	A measure of the central tendency of a set of values. The median is the mid-point value of the ordered set, with as many samples having values greater than the median as there are samples with values less than the median.

TECHNICAL APPROACH

Geochimica based its analysis on the underlying principal of conservation of mass, in hydrogeochemical studies usually called "mass balance" or loading analysis. An attempt is made to identify sources of mass (for example dissolved zinc) in surface waters, then a measure of both (a) the flow of water [in units of Volume/Time, e.g., liters/sec, gallons/minute, etc.)] and (b) the concentration of the substances of interest in that flowing water [in units of Mass/Volume, e.g., mg/L]. If the flow and concentration are reported in compatible units, then the mass flux (load) is the product of the flow times the concentration [in units of Mass/Time, for example, (L/s * mg/L) = mg/s, which can then be converted to equivalent units such as tons/year.

Because mass can neither be created nor destroyed, the mass loading should increase downstream in an orderly fashion, with the load at a downstream point equaling (within the propagated uncertainties of the input data) the sum of the upstream loads. If the downstream load is significantly greater than the apparent sum of the upstream loads, then there must be additional sources. If the downstream load is less than the sum of the upstream loads, then mass is not conserved in the aqueous system and a field inspection is conducted to look for evidence of precipitation, or perhaps loss of flow from the surface system to groundwater in losing reaches of streams.

The basic measurements of flow and concentrations in aqueous solution are subject to a range of uncertainties. It is Geochimica's understanding that there has not been a fundamental analysis of such data uncertainties underlying the databases of the Stakeholder Group, for example the accuracy and precision of flow measurements. However, all the sources of data are from entities experienced in sampling and analysis, so we can suppose that flow measurements are accurate to about +/- 20% and the analytical data (at levels higher than about 10 times the detection limit) will be accurate to about +/- 10% of the reported values. To a good approximation, the joint uncertainty for load should be approximately the square root of the sum of the squares of the two, or +/- 22%. Mass balance studies are widely used in the hydrological sciences, and despite this apparent uncertainty, experience shows that the results are highly useful for understanding the roles of sources and pathways in producing conditions for receivers at downstream locations.

For this analysis, Geochimcia concentrated on a single year, 2010, compiling all available data across the full year so that ranges of flow could be examined and the consistency of the mass balances understood in terms of hydrologic variation across the full annual hydrograph. Geochimica selected 2010 because, at the time of the initiation of this analysis, it was the most recent data reported for a full year, and it is a fair representation of current conditions in the upper Animas River watershed. The results are presented for the annual low flow (March 2010) and the annual high flow (June 2010) condition, and also for calculated values of median flow over the observed range for the full year. These three conditions allow evaluation of how the mass balance responds to the annual hydrograph conditions, with no outliers (because we use the measured minimum and maximum flow conditions). Specific values for flow and water quality would almost surely differ from year to year, but the general trends and relative proportions should be consistent. In years with higher flow, there would be greater dilution, and sources located at higher elevations above stream levels in what usually is the vadose zone (and so would not be rinsed except at exceptionally high infiltration and flow conditions) may be activated. In years with lower flow, more of the annual results would look like those for Low Flow in the 2010 data. But the general behavior of the system is not expected to change, barring major climatic or tectonic changes that would fundamentally alter the physical flow system .

METHODS AND PROCEDURES

Mass-balance analysis in stream flow systems, involving simple products and sums, is very well suited to spreadsheet analysis. Geochimica's analyses use Microsoft Excel. The relevant spreadsheets are provided in their entirety in the attachments to this memorandum. The Excel model includes the following components as separate worksheets:

- Cover (identifying the author, date, and controlling design data)
- Flow and Concentration Data A68; CC48; Adits; M34; A72
- Data Summary: Flow and Zn Mass
  [Note that Zn mass was selected for mass balance because of its conservative properties over the pH range expected to be observed in the upper Animas River Basin. In addition, water-treatment approaches that would be effective for Zn also would be effective for other pH-sensitive trace metals.]
- Flow and Zn Balance - Adits
- Flow Balance at A72, includes CC48
- Mass Balance at A72, includes CC48
- A72 - Adit Mass (calc), includes CC48
- Summary and Conclusions

An example of the use of a spreadsheet for the Flow*Concentration = Mass Load/Unit Time is shown in Table 1.

Table 1. Flow and concentration data and mass-loading for discharge from the American Tunnel during 2010 (From Attachment 2 to this memo).

Adits			cfs	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	kg/d
Name	**Site**	DATE	Q	pH	Al	Cd	Cu	Fe	Mn	Pb	Zn	**Zn Load**
American Tunnel	CC19	2/17/10	0.178	5.19	5.180	0.0022	0.0057	148.0	49.5	0.0014	19.9	
American Tunnel	CC19	3/18/10	0.204	4.46	4.810	0.0023	0.0083	145.0	50.3	0.0018	20.6	
American Tunnel	CC19	4/13/10	0.204	5.38	4.710	0.0025	0.0062	159.0	49.7	0.0020	18.4	
American Tunnel	CC19	6/2/10	0.240	5.29	4.200	0.0022	0.0050	136.0	44.5	0.0022	17.6	
American Tunnel	CC19	7/13/10	0.240	5.26	4.590	0.0022	0.0050	157.0	49.9	0.0025	19.7	
American Tunnel	CC19	9/14/10	0.268	4.47	4.930	0.0020	0.0020	164.0	51.4	0.0025	20.4	
American Tunnel	CC19	11/2/10	0.240	5.17	4.660	0.0025	0.0020	142.0	49.1	0.0015	21.4	
Low		**3/18/10**	**0.204**	4.46	4.810	0.0023	0.0083	145.0	50.3	0.0018	20.6	**10.3**
Median		**Median**	**0.240**	5.19	4.710	0.0022	0.0050	148.0	49.7	0.0020	19.9	**11.7**
High		**6/2/10**	**0.240**	5.29	4.200	0.0022	0.0050	136.0	44.5	0.0022	17.6	**10.3**

Notes: Below detection results are shown as ½ reporting limit. These values are highlighted in Attachment 2 data.
Yellow highlighted value is resultant of example calculation below.
The loading calculation for kg/d is Flow (cfs) x concentration (mg/l) x constant (2.4451)= Load kg/d

For example, on 3/18/10 the flow (Q) from the American Tunnel, measured at Station CC19, was 0.204 cfs (cubic feet per second, or ft^3/s), and its Zinc concentration was 20.6 mg/L (milligrams per liter). The mass load per unit time would be:

$$(0.204\ ft^3/s * 20.6\ mg/L) * [2,4451 * (kg*s*L) / (d * ft^3 * mg)] = 10.3\ kg/d \text{ of Zn}$$

DATA

Attachment 2 to this memorandum includes the entire analytical report of the mass-balance analysis.

Key data and results for the four scoping issues identified above are presented in the Discussion section below.

DISCUSSION

The technical issues raised by the results are organized in a step-wise fashion that reflects the logic of mass-balance analysis for surface waters. The first step is determining proportions of water flow, both because flow is needed to calculate mass balance, and because the water flows provide an initial test of the coherence of the data set. Then, because it is important to know how the flowing adits in upper Cement Creek contribute to water quality at A72, an analysis is done of the loadings within Cement Creek drainage itself. Finally the adit contributions are extended to the combined system drainage at A72. As usual in a technical analysis, there is an uncertainty analysis.

1. In what proportions do the three sub-drainages contribute to the water flow system observed at Station A72?

To understand the impacts of sources within the three sub-drainages on observed conditions at Station A72, an understanding how monitored flow for each sub-drainage contributes to the total flow measured at A72 is needed. The monitoring points for the three sub-drainages are A68 (Upper Animas River), CC48 (Cement Creek), and M34 (Mineral Creek).

The calculations of their contributions to flow at A72 are computed in the spreadsheet "Flow Balance at A72" in Attachment 2, and summarized below in Table 2. The dates of the Low and High Flow events are given in format (month/day/year). Percentage of the flow at A72 is calculated as Flow (sub-basin)/Flow Observed at A72, e.g., (18.9/51.6)*100 = 36.6%

Table 2. Summary Flow Values for Stations A68, CC48, M34 and A72 (2010). Flows are in units of cfs (ft^3/s), and those measured values are recalculated as percentages (%) of the total flow at Station A72. RPD is Relative Percent Difference between the Sub-Total flow for the three river stations and the Observed Flow at Station A72.

River Station	Low Flow	% Total Flow	Median Flow	% Total Flow	High Flow	% Total Flow
A68	18.9	36.6%	58	30.7%	517	32.7%
CC48	13.7	26.6%	19	10.1%	137	8.7%
M34	17.9	34.7%	61.9	32.8%	576	36.5%
Sub-Total	50.5		138.9		1230	
A72 Observed	51.6		189		1580	
RPD	1.1%		15.3%		12.5%	

For example, the RPD for Low Flow = (51.6-50.5)/(51.6+50.5) = .011 = 1.1% RPD values in the range of 12% - 15%, as calculated for the Median and High Flow cases are commonly encountered in high energy streams with high and spatially ranging velocities and irregular and sometimes changing cross sections.

The table shows that under Low-Flow conditions each of the three sub-basins contributes about 1/3 of the total flow observed at Station A72. Although the absolute value of the water flow measured at CC48 rises from the Low-Flow (13.7 cfs) to the High-Flow (137 cfs) condition, the absolute values of total flows measured at A72 rise at a faster rate. Therefore, the percentage contribution of CC48 falls from 27% of total flow at A72 at Low Flow to only 9% of total flow at A72 under High Flow. This is due to the limited surface area of the Cement Creek sub-drainage compared to the total drainage area to A72. Under Low Flow conditions, most of the flow is due to groundwater seepage to creeks, whereas under High Flow conditions, the source of runoff is snow melt, and the larger surface areas dominate the total flow to A72.

2. In what proportions do the four maj or discharging adits in upper Cement Creek contribute to metal loads at Station CC48?

The four major discharging adits in the Cement Creek drainage are American Tunnel (AT), Gold King (GK), Red and Bonita (RB), and Mogul adits.

The calculation of mass loadings for Zn from the four adits is presented in Spreadsheet "Flow and Zinc Balance – Adits" in Attachment 2. The key results are reproduced in Table 3 and Figures 1 and 2 for measured Low Flow, Median Flow (calculated) and measured High Flow in 2010. The results are presented both in the table and visually as pie -graphs showing proportions of loading to total adit loading (Figure 1) and total stream loads (Figure 2).

Table 3. Mass Loading of Zn from the Four Major Discharging Adits to Total Mass loading of Zn at Station CC48. Loading in kg Zn/day, except proportion of CC48 in percent of total load at CC48.

Stations	3/17/21010 Low Flow		Calculated Median Flow		6/2/2010 High Flow
AT	10.28		11.68		10.33
GK	11.07		23.90		53.62
RB	15.73		17.38		17.52
Mogul	11.29		9.11		7.73
Sub-Total	48.36		62.06		89.20
CC48 Observed	87.10		110.18		222.41
Non-Adit Mass Load	38.74		48.12		133.21
Adit Proportion of CC48	55.5%		56.3%		40.1%
Non-Adit Proportion of CC48	44.5%		43.7%		59.9%

As shown in the second to last row of the Table 3, the mass loading from the four major discharging adits accounts for 40% to 56% of the total Zn loading observed at CC48. The higher absolute value of total Zn discharge and the lower percentage released under High Flow conditions shows that there are other sources of Zn in the Cement Creek drainage, as quantified by difference in the last row of Table 3. The proportion of non-adit water (60%) is greatest under High Flow conditions. The available monitoring data cannot reveal where the other sources are, nor whether they are point-source or distributed flow.

The four discharging adits occupy a very small proportion of the Cement Creek drainage, and all of that is near the headwaters of the creek. Because precipitation, reporting as runoff and base-flow, affects the entire sub-drainage, there is no physical basis for believing that the sum of the adit flows and loads would equal the total flow or load of Cement Creek. Therefore, it is not appropriate to calculate a RPD value for the precision of the two measurements.

Under Low Flow conditions (March, 2010), each of the four discharging adits releases almost equivalent mass loads of Zn in kg/d, ranging from 10.3 kg/d (21%) from the American Tunnel to 15.7 kg/d (33%) from the Red and Bonita Mine. However, under High Flow conditions (June, 2010), mass loading is dominated by discharges from the Gold King Mine, 53.6 kg/d (60% of the total Zn released from the adits to CC48). Under High Flow conditions, the American Tunnel releases 10.3 kg Zn/d, indistinguishable from the value under Low Flow conditions for the 2010 monitoring data, but at High Flow, this is only 11% of the total Zn load from the adits to CC48. This indicates that Gold King is more influenced by surface flow conditions than is the American Tunnel.

Figure 1. Proportion of Loading from Each Adit to Total Adit Loading for Each Flow Condition.

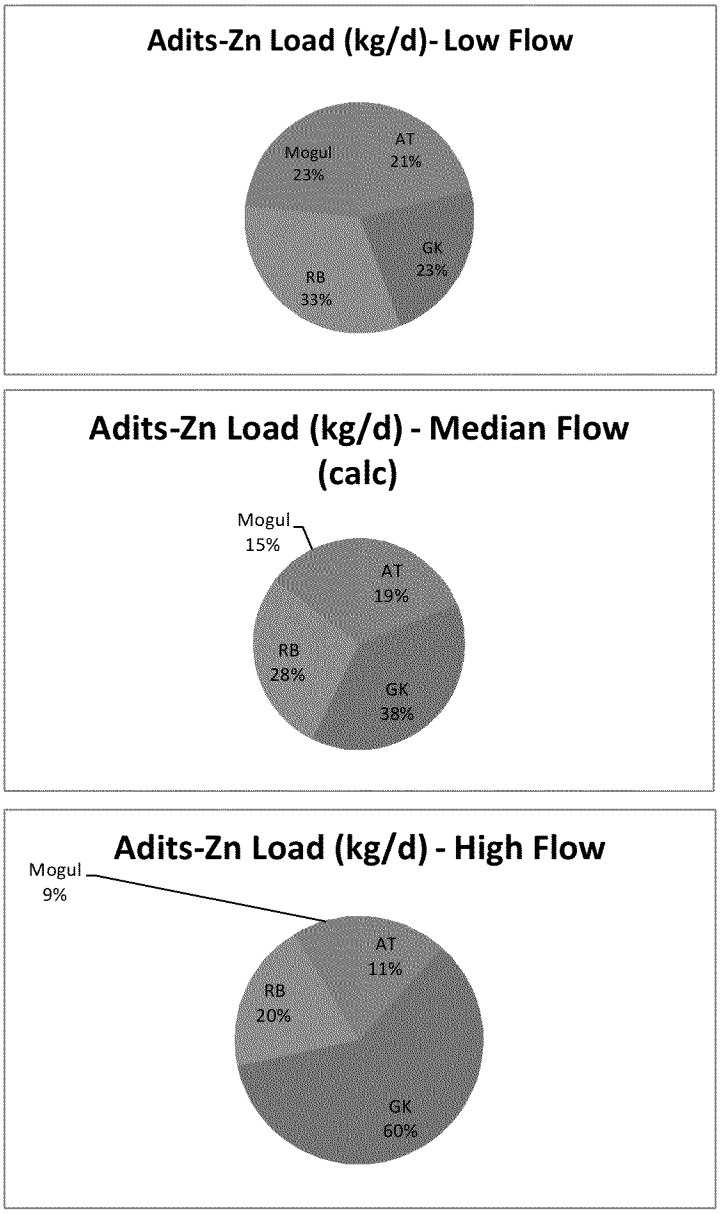
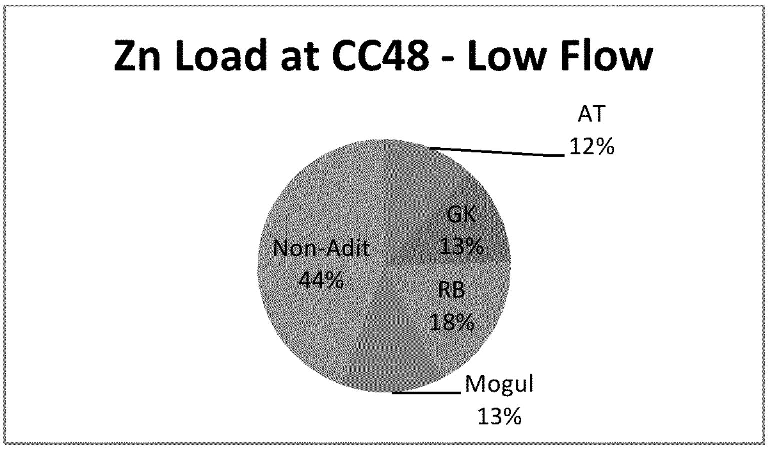
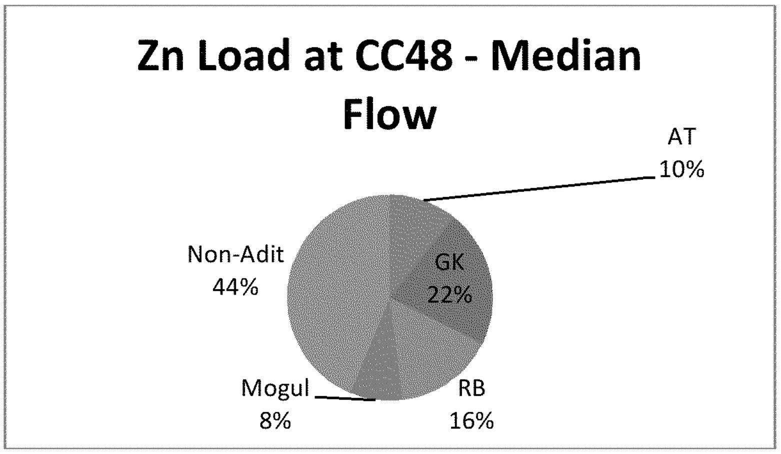
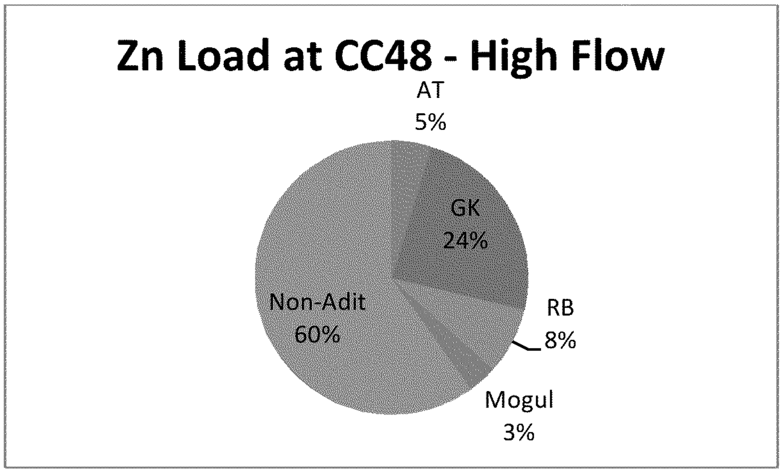


Figure 2. Proportions of Adit and Non-Adit Flows at Station CC-48







3. In what proportions do the four major discharging adits in upper Cement Creek contribute to the metal loadings observed at Station A72?

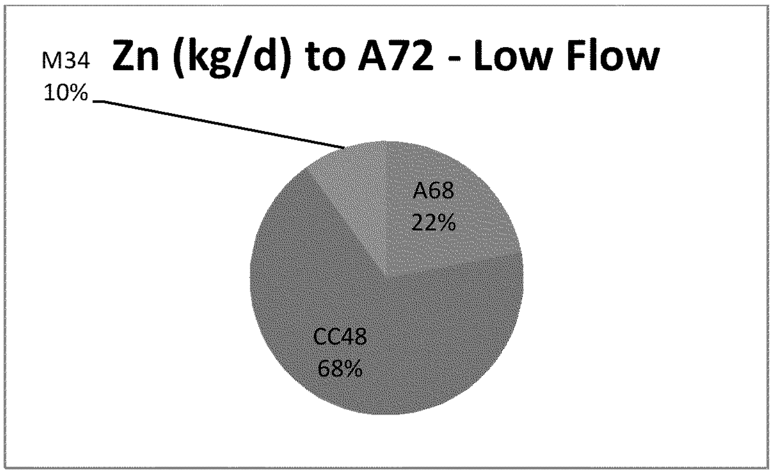
The analysis of flow from the three sub-drainages can be expanded to mass-loading using the procedures described in Technical Approach and Methods and Procedures above. The analysis is presented in spreadsheet "Mass Balance at A72" in Attachment 2, and the principal results are summarized in Table 4 and Figure 3 in graphical form.

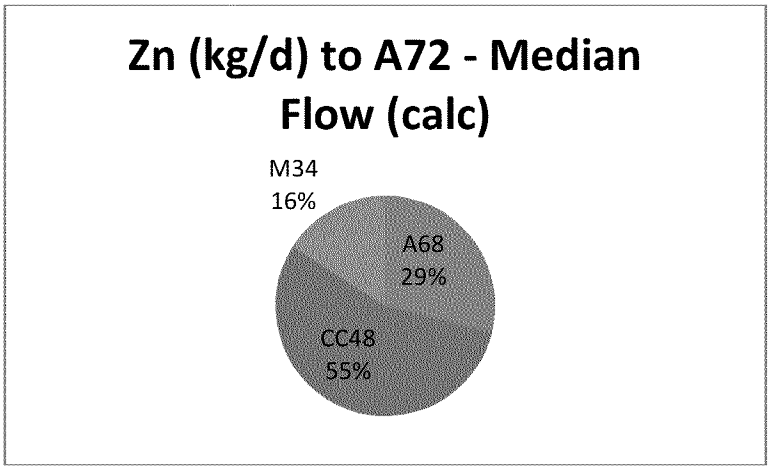
Table 4. Mass Loading of Zinc from the three sub-basins to total mass loading of Zn at Station A72. Loading in kg Zn/day, except proportion of load in percent of total load at A72, and calculation of Relative Percent Difference (RPD) between load inferred as sum of the sub-basin drainages and the measured load at A72, also in percent.

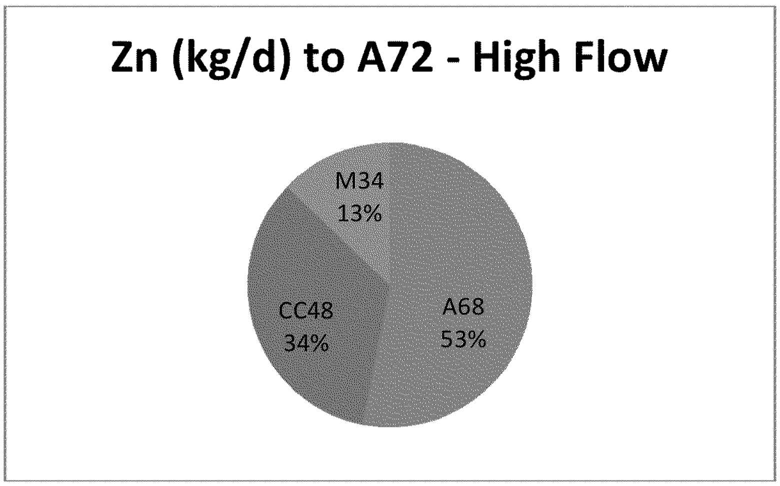
	3/17/2010			Calculated			6/2/2010	
	Low Flow	**% of Sub-Basins**		**Median**	**% of Sub-Basins**		**High Flow**	**% of Sub-Basins**
A68	28.2	22%		57.8	29%		347.4	53%
CC48	87.1	68%		110.2	55%		222.4	34%
M34	12.8	10%		31.9	16%		84.7	13%
Total	128.1			199.8			654.6	
A72 Observed	151.4			283.3			795.8	
RPD	8.4%			17.3%			9.7%	
RPD =(A72 obs – Total) / (A72 obs + Total)								

The results of the mass-loading calculations show that under Low and Median Flow conditions, Cement Creek (CC48 in Table 4) is the dominant sub-drainage for loading of Zn at Station A72, ranging from 55% under Median Flow to 68% of the total Zn loading under Low Flow conditions. However, under High Flow conditions, the upper Animas River (A68 in Table 4) produces 53% of the total load, and Cement Creek (CC48) has been reduced to 34% of the total Zn mass loading at A72.

Figure 3. Pie charts of Mass Loading of Zinc from the three sub-basins to total mass loading of Zn at Station A72







From this analysis and the results of the Cement Creek analysis shown in Table 3 above, an immediate calculation can be made of the contribution of the four major discharging adits in Upper Cement Creek to the total Zinc loading at Station A72. The percentage contribution of the adits to total Zinc loading at A72 is (Percentage of Cement Creek Load at A72) * (Percentage of Adit Loading to Zinc Load at CC48). The results are shown in Table 5 below.

Table 5. Calculation of Zinc Loading at Station A72 Due to Zn Loading from the Four Major Discharging Adits.

Flow Condition	Percent Stream Contribution of CC48 to A72 Zn Load (Table 4)	Percent Adit Contribution to CC48 Zinc Load (Table 3)	Percent Adit Contribution to A72 Zn Load (Column 2 times Column 3)
Low Flow (March, 2010)	68%	55.5%	37.8%
Median Flow (calculated)	55%	56.3%	31.0%
High Flow (June, 2010)	34%	40.1%	13.6%

The calculations indicate that the four major discharging adits (American Tunnel, Gold King, Red and Bonita, and Mogul) constitute 14% to 38% of the total Zinc loading observed at Station A72 in 2010. The proportional contribution is greatest under Low to Median Flows, and least under High Flow.

4. What are the uncertainties in the loading analysis at this time.

As shown in Table 2, the range of flow balance in the entire system reporting to A72 is from 1.1% relative percent difference (RPD) for Low Flow to 15.3% RPD for Calculated Median Flow. The RPD is 12.5% at High Flow). These closures of flow are good in terms of hydrological balances and in light of uncertainties in field flow measurements. The good agreement suggests that existing errors are within commonly acceptable error limits for measuring flow.

As shown in Table 4, the range of mass balance in the entire system reporting to A72 is from 8.4% RPD for Low Flow to 17.3% RPD for Calculated Median. The RPD is 9.7% for High Flow conditions. These closures of mass balance for Zn are good in terms of hydrochemical balances and in light of uncertainties in field flow measurements, commonly considered to be up to +/- 20% in high-energy systems, and analytical reproducibility of water chemistry, which typically is +/- 10% for values above detection limits. Agreement of less than 15% suggests that existing uncertainties are within commonly acceptable error limits for measuring flow and dissolved chemistry. Because the uncertainty limits for flow are approximately twice as high as for concentrations, most of the apparent uncertainty

probably derives from the flow. The uncertainties in flow measurement encompass both reproducibility of velocity measurements at multiple points on a cross section, plus variability over time and uncertainty in the measurement of cross-sectional area of flow. Especially under higher flow conditions, both velocity and cross section become more difficult to measure with precision. In contrast standard laboratory QA/QC procedures are used to control analytical precision and reproducibility, and these standard conditions are better controlled in the laboratory than are field conditions for flow.

CONCLUSION

Based on the 2010 data, under Low Flow and Median Flow conditions, the four major discharging adits contribute 31% to 38% of the total Zinc loading observed at Station A72. This indicates that control of Zinc currently being released from the four adits is very important to being able to achieve significant reductions in load (and therefore concentrations) at Station A72 under the flow conditions expected over most of the year.

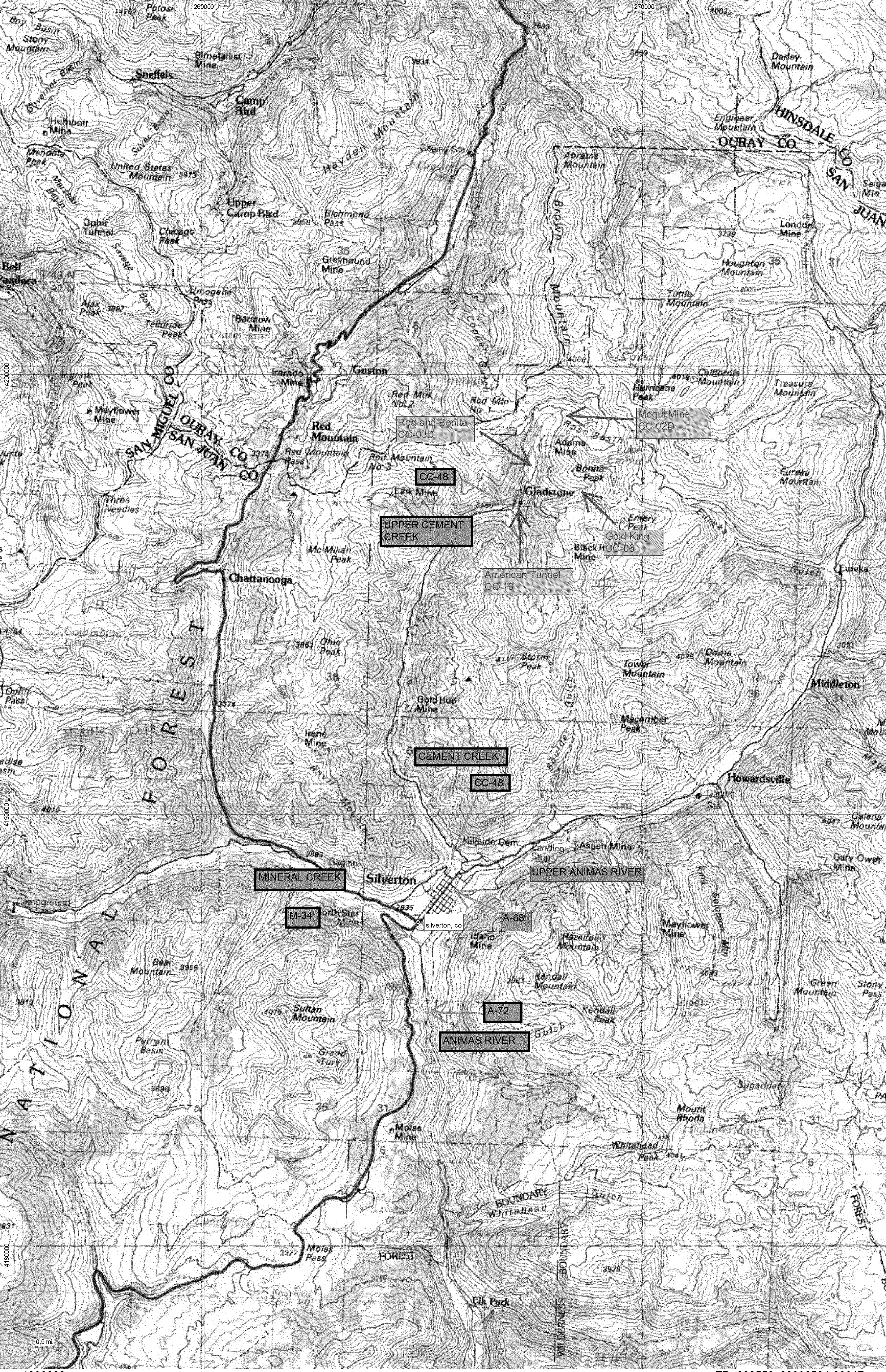
Under High Flow conditions, which reflect the snow-melt hydrograph for the high-mountain environment, the four adits contribute about 14% of the load at A72. This suggests that if a water-treatment plant were implemented, it may not be necessary for it to be designed for the maximum flow conditions, because bypass of a portion of the actual flow under High Flow conditions will have only a modest impact on the observed loading and concentrations at A72. The expected value near 14% suggests that, given uncertainties in measurements of both flow and concentration, the residual Zinc above that which could be captured in adit treatment at High Flow may be within the total uncertainty of measurements.

REFERENCE

Mast, M.A., P.L. Verplanck, W.G. Write, and D.J. Bove, 2007. Characterization of Background Water Quality, in S.E. Church, P. von Guerard and S.E. Finger (Eds), Integrated investigations of Environmental Effects of Historical Mining in the Animas River Watershed, San Juan County, Colorado. U.S. Geological Survey Professional Paper 1651, Vol. 1,p. 347-386.

Attachment 1

Location Map


Mogul Mine
CC-02D
Red and Bonita
CC-03D
CC-48
UPPER CEMENT CREEK
Gold King
CC-06
American Tunnel
CC-19
CEMENT CREEK
CC-48
MINERAL CREEK
UPPER ANIMAS RIVER
M-34
silverton, co
A-68
A-72
ANIMAS RIVER
Silverton
Gladstone
Chattanooga
Howardsville
Middleton
Eureka
Red Mountain
OURAY CO
SAN JUAN CO
SAN MIGUEL CO
HINSDALE CO
0.5 mi

Attachment 2

Mass Loading Calculations

FLOW AND MASS BALANCES AT CC48 AND A72 IN 2010

Calculated for	Minimum Q (with observed Zn)			
	Median Q and Zn			
	Mamximum Q (with Observed Zn)			
Analysis for CC48 shows		Min Q on	17 Mar 2010	(13.7 cfs)
		Max Q on	02 Jun 2010	(137 cfs)

Match Dates at Other Stations as Closely as Possible

Focus of Study: Contributions of 4 Discharging Adits in upper Cement Creek to Total Flow and Mass Loading at CC-48, and to Flow and Mass Loading at A72

Use Zn as Analytical Key: Effectively Conservative at Low pH and Essential to Compliance and Water-Treatment Evaluation

Mark Logsdon (11 July, 2012) - Calculations Initiated January 2012
Geochimica, Inc.
Aptos CA

ToC:

A68 DATE	CFS Q	su pH	mg/L Ca	mg/L Mg	mg/L Na	mg/L K	mg/L SO4	mg/L TDS	mg/L Al	mg/L Cd	mg/L Cu	mg/L Fe	mg/L Mn	mg/L Pb	mg/L Zn
2/17/2010		6.74	73.90	4.13	3.26	0.50	167	300	0.141	0.0018	0.0015	0.050	3.56	0.0005	0.702
3/2/2010		7.95	66.66	3.41	2.36	0.69			0.122	0.0016	0.0050	0.185	2.76		0.530
3/17/2010	18.9	6.82	65.60	3.81	3.39	0.50	153	268	0.050	0.0016	0.0015	0.050	2.71	0.0005	0.610
4/13/2010	50.0	6.85	53.60	3.49	2.92	0.50	130		0.050	0.0041	0.0083	0.050	3.73	0.0005	0.985
4/16/2010		7.83	61.44	3.80	2.62	0.65			0.210	0.0029	0.0081	0.128	4.32		0.934
5/5/2010	131.1	6.67	34.58	2.04	1.73	0.50	70	143	0.075	0.0013	0.0072	0.050	1.05	0.0010	0.443
6/2/2010	517.0	7.39	17.72	1.24	1.26	0.47	33	81	0.043	0.0009	0.0272	0.037	0.33	0.0005	0.275
7/8/2010	125.0	6.75	32.47	2.06	1.60	0.49	67	120	0.040	0.0008	0.0029	0.051	0.74	0.0024	0.274
7/13/2010	81.0	6.92	34.90	2.31	1.65	0.50	71	150	0.050	0.0008	0.0500	0.050	0.65	0.0005	0.261
8/10/2010		7.59	33.47	2.60	1.14	0.52			0.067	0.0012	0.0034	0.058	1.31		0.304
9/9/2010	73.0	7.09	46.78	2.91	1.90	0.86	100	213	0.040	0.0011	0.0030	0.035	1.21	0.0005	0.331
9/14/2010	44.0	7.52	52.40	3.25	2.29	0.09	101	324	0.013	0.0013	0.0020	0.005	1.31	0.0001	0.410
10/4/2010		6.67	48.80	2.71	1.74	0.59			0.055	0.0009	0.0030	0.085	1.42		0.337
11/2/2010	36.0	7.26	56.30	3.27	2.82	0.09	109	210	0.013	0.0014	0.0020	0.005	1.79	0.0001	0.436
11/3/2010	58.0	7.40	50.12	2.92	2.04	0.55	108	173	0.045	0.0011	0.0029	0.057	1.39	0.0020	0.351
12/7/2010	55.0	8.25	48.62	2.82	2.31	0.64			0.086	0.0012	0.0034	0.085	1.29	0.0015	0.405

DATE	CFS Q	su pH	mg/L Ca	mg/L Mg	mg/L Na	mg/L K	mg/L SO4	mg/L TDS	mg/L Al	mg/L Cd	mg/L Cu	mg/L Fe	mg/L Mn	mg/L Pb	mg/L Zn
Min	18.9	6.67	17.7	1.24	1.14	0.09	33	81	0.013	0.0008	0.0015	0.005	0.33	0.0001	0.261
10%	36.0	6.71	33.0	2.05	1.43	0.28	67	116	0.026	0.0008	0.0018	0.020	0.69	0.0001	0.275
15%	40.0	6.74	33.7	2.13	1.62	0.47	69	128	0.040	0.0009	0.0020	0.035	0.82	0.0004	0.282
25%	47.0	6.80	34.8	2.53	1.71	0.50	70	145	0.042	0.0010	0.0026	0.046	1.17	0.0005	0.324
Median	58.0	7.18	49.5	2.91	2.16	0.50	101	192	0.050	0.0012	0.0032	0.050	1.35	0.0005	0.407
75%	103.0	7.54	57.6	3.43	2.67	0.60	120	254	0.078	0.0016	0.0074	0.065	2.72	0.0011	0.550
85%	128.1	7.77	64.6	3.72	2.90	0.65	142	289	0.113	0.0018	0.0083	0.085	3.36	0.0017	0.679
90%	131.1	7.89	66.1	3.81	3.09	0.67	153	302	0.132	0.0024	0.0177	0.107	3.65	0.0020	0.818
Max	517.0	8.25	73.9	4.13	3.39	0.86	167	324	0.210	0.0041	0.0500	0.185	4.32	0.0024	0.985
Avg	108.1	7.23	48.6	2.92	2.19	0.51	101	198	0.069	0.0015	0.0082	0.061	1.85	0.0008	0.474
StDev	140.0	0.50	14.9	0.76	0.68	0.19	40	80	0.051	0.0009	0.0128	0.044	1.20	0.0007	0.226
cv	1.3	0.07	0.31	0.26	0.31	0.38	0.39	0.40	0.742	0.5859	1.5546	0.722	0.65	0.8727	0.476
IQR	56.0	0.73	22.8	0.90	0.96	0.10	49	110	0.036	0.0005	0.0048	0.019	1.56	0.0006	0.226
Low Flow															
3/17/2010	18.9	6.82	65.60	3.81	3.39	0.50	153	268	0.050	0.0016	0.0015	0.050	2.71	0.0005	0.610
Medians															
Median	58.0	7.18	49.5	2.91	2.16	0.50	101	192	0.050	0.0012	0.0032	0.050	1.35	0.0005	0.407
11/3/2010	58.0	7.40	50.12	2.92	2.04	0.55	108	173	0.045	0.0011	0.0029	0.057	1.39	0.0020	0.351
Max Flow															
6/2/2010	517.0	7.39	17.72	1.24	1.26	0.47	33	81	0.043	0.0009	0.0272	0.037	0.33	0.0005	0.275

Average of multiple splits
Value = 1/2 LOD

Zn Loads	kg/d *	lb/d				
Low Q	28.2	62.0				
Median Q	57.8	127.1				
Max Q	347.4	764.4				
	cfs *mg/L					
	times	2.4451	kg/d			
			times	2.20	5.38	lb/d

	Q	pH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
Q	1														
pH	0.051462	1													
Ca	-0.81591	0.096095	1												
Mg	-0.81237	0.09559	0.96076	1											
Na	-0.63411	-0.05837	0.876507	0.868766	1										
K	0.063395	0.101224	0.019072	-0.01916	-0.1649	1									
SO4	-0.76983	-0.2569	0.980558	0.977692	0.945729	-0.01111	1								
TDS	-0.67153	0.074059	0.873558	0.902161	0.797095	-0.29968	0.828114	1							
Al	0.043888	0.319612	0.440031	0.428572	0.27239	0.460854	0.417801	0.165342	1						
Cd	-0.26645	0.018971	0.455031	0.573368	0.581717	0.034363	0.520744	0.784328	0.40331	1					
Cu	0.407143	-0.09469	-0.48872	-0.47103	-0.3683	0.014976	-0.5319	-0.49467	-0.07123	-0.16511	1				
Fe	-0.03331	0.453431	0.328524	0.223938	0.04372	0.591479	0.079537	-0.36965	0.71094	0.192358	-0.05789	1			
Mn	-0.50869	0.07631	0.797731	0.849401	0.773246	0.132856	0.895323	0.752818	0.678483	0.836081	-0.32937	0.416816	1		
Pb	-0.02917	0.094464	-0.27202	-0.32132	-0.36131	0.378122	-0.24113	-0.48062	0.132133	-0.27797	-0.19262	0.619222	-0.29567	1	
Zn	-0.34249	0.016038	0.639122	0.714457	0.733225	0.071493	0.720891	0.719425	0.584798	0.945392	-0.23838	0.288722	0.945963	-0.30844	1

CC48 data entry and conversions,07Jan12; checked 08Jan12 AVERAGING SPLITS

DATE	CFS		mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Q	PH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
2/17/2010		3.50	208.50	11.85	5.21	2.02	603.50	960.00	8.42	0.01	0.12	13.25	5.28	0.01	2.67
3/2/2010		3.43	201.1	12.4	4.7	2.2			8.075	0.0052	0.133	12.844	5.346	0.015	2.676
3/17/2010	13.70	3.42	198.00	11.20	5.76	2.10	529.00	940.00	7.82	0.01	0.11	9.64	5.20	0.01	2.60
4/6/2010		3.5	194.6	11.3	4.6	2.2			7.996	0.0055	0.129	13.628	5.349	0.016	2.681
4/13/2010	26.40	3.93	108.00	6.99	3.52	1.29	355.00		4.83	0.00	0.11	8.54	3.01	0.01	1.58
5/5/2010	40.00	4.15	75.46	5.07	2.08	1.07	246.00	351.00	3.17	0.00	0.09	6.37	2.16	0.01	1.41
6/2/2010	137.00	5.15	30.64	2.43	1.31	0.54	104.00	170.00	0.98	0.00	0.07	2.38	0.83	0.01	0.66
7/8/2010	25.00	3.05	108.49	6.94	2.78	1.11	370.00	521.00	4.32	0.00	0.12	3.07	2.70	0.02	1.55
7/13/2010	21.00	3.57	125.00	8.04	3.45	1.52	374.00	620.00	5.09	0.00	0.12	4.30	3.28	0.02	1.80
8/10/2010		3.57	125.6	8.7	2.8	1.4			5.942	0.0056	0.184	5.034	3.491	0.018	2.026
9/9/2010	17.00	3.04	155.08	9.19	3.90	1.88	542.00	807.00	6.54	0.01	0.18	5.34	4.17	0.02	2.26
9/14/2010	15.00	3.45	183.50	10.90	4.67	2.02	506.50	818.00	7.38	0.01	0.16	8.93	4.99	0.02	2.67
10/4/2010		3.27	156.5	9.3	3771.0	1.7			6.695	0.0061	0.178	8.209	4.729	0.022	2.487
11/2/2010	15.00	3.51	183.50	11.35	4.90	2.05	535.00	880.00	7.56	0.01	0.14	11.40	5.17	0.02	2.88
11/3/2010	14.00	3.20	162.00	9.77	3.91	1.87	578.00	820.00	6.68	0.01	0.16	8.65	4.52	0.02	2.47
12/7/2010		3.36	166.9	9.7	4.6	2.1			6.694	0.0054	0.131	9.532	4.516	0.017	2.272

	provisional		mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	FLOW_CFS	PH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
Min	13.70	3.04	30.64	2.43	1.31	0.54	104.00	170.00	0.98	0.00	0.07	2.38	0.83	0.01	0.66
10%	13.97	3.13	91.73	6.01	2.43	1.09	246.00	332.90	3.74	0.00	0.10	3.69	2.43	0.01	1.48
15%	14.35	3.22	108.12	6.96	2.78	1.16	300.50	410.50	4.45	0.00	0.11	4.48	2.78	0.01	1.55
25%	15.00	3.34	120.87	7.78	3.28	1.39	362.50	545.75	5.03	0.00	0.12	5.27	3.21	0.01	1.74
Median	19.00	3.48	159.27	9.51	4.23	1.88	506.50	812.50	6.69	0.01	0.13	8.60	4.52	0.02	2.37
75%	26.05	3.57	186.28	11.23	4.75	2.06	538.50	865.00	7.63	0.01	0.16	10.08	5.18	0.02	2.67
85%	35.24	3.84	197.16	11.34	5.13	2.09	560.00	919.00	7.95	0.01	0.17	12.48	5.26	0.02	2.67
90%	49.70	4.04	199.56	11.60	5.48	2.14	578.00	942.00	8.04	0.01	0.18	13.05	5.31	0.02	2.68
Max	137.00	5.15	208.50	12.37	3771.00	2.22	603.50	960.00	8.42	0.01	0.18	13.63	5.35	0.02	2.88
Avg	32.41	3.57	148.93	9.07	239.32	1.69	431.18	688.70	6.14	0.01	0.13	8.19	4.05	0.02	2.17
StDev	37.64	0.51	50.04	2.68	941.78	0.49	156.11	266.09	2.02	0.00	0.03	3.54	1.34	0.00	0.61
cv	1.16	0.14	0.34	0.30	3.94	0.29	0.36	0.39	0.33	0.20	0.24	0.43	0.33	0.23	0.28
IQR	11.05	0.23	65.41	3.45	1.46	0.66	176.00	319.25	2.60	0.00	0.04	4.81	1.97	0.00	0.92
Low Flow	**cfs**														**Zn**
3/17/2010	13.70	3.42	198.00	11.20	5.76	2.10	529.00	940.00	7.82	0.01	0.11	9.64	5.20	0.01	2.60
Medians															
Median	19.00	3.48	159.27	9.51	4.23	1.88	506.50	812.50	6.69	0.01	0.13	8.60	4.52	0.02	2.37
7/13/2010	21.00	3.57	125.00	8.04	3.45	1.52	374.00	620.00	5.09	0.00	0.12	4.30	3.28	0.02	1.80
9/9/2010	17.00	3.04	155.08	9.19	3.90	1.88	542.00	807.00	6.54	0.01	0.18	5.34	4.17	0.02	2.26
Max Flow															
6/2/2010	137.00	5.15	30.64	2.43	1.31	0.54	104.00	170.00	0.98	0.00	0.07	2.38	0.83	0.01	0.66

Average of multiple splits
Value = 1/2 LOD

Zn Loads	**kg/d ***	**lb/d**
Low Q	87.1	191.6
Median Q	110.2	242.4
Max Q	222.4	489.3

Convert	cfs*mg/L												
	times	2.83E+01	L/s										
			times		60	60	24						
				s/min	min/hr	hr/d	L/d						
							times	[Zn]					
								mg/L					
								times	1.00E-03	1.00E-03			
									g/mg	kg/g	kg/d		
											times	2.2	
												lb/kg	lb/d
	cfs *mg/L												
	times	2.44512	kg/d										
			times	2.2	5.379264	lb/d							

	Q	PH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
Q	1														
PH	0.89345	1													
Ca	-0.80428	-0.69804	1												
Mg	-0.8248	-0.70952	0.99103	1											
Na	-0.74299	-0.15793	0.041738	0.024334	1										
K	-0.7992	-0.68054	0.973258	0.966953	-0.0156	1									
SO4	-0.83705	-0.82158	0.957623	0.958357	0.891431	0.953717	1								
TDS	-0.82274	-0.74625	0.991296	0.988106	0.968018	0.982247	0.976516	1							
Al	-0.83631	-0.72408	0.990746	0.992255	0.074687	0.964699	0.968211	0.993707	1						
Cd	-0.85443	-0.79369	0.79146	0.818027	0.237824	0.790041	0.919391	0.896887	0.844554	1					
Cu	-0.66792	-0.68714	0.436775	0.482811	0.374378	0.447008	0.745784	0.646739	0.51846	0.737686	1				
Fe	-0.58832	-0.3077	0.824775	0.811121	0.002071	0.810619	0.724021	0.799017	0.812046	0.586862	0.083984	1			
Mn	-0.79797	-0.69697	0.989546	0.984511	0.137008	0.973224	0.958169	0.988212	0.989655	0.841876	0.497394	0.830433	1		
Pb	-0.72045	-0.82807	0.277275	0.309427	0.41057	0.252774	0.498602	0.387686	0.326788	0.592636	0.723645	-0.11776	0.313884	1	
Zn	-0.78679	-0.70584	0.96883	0.973297	0.139685	0.955459	0.948598	0.969903	0.975899	0.8853	0.555699	0.794763	0.988268	0.349203	1

Adits			cfs	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	kg/d	cfs *mg/L	
Name	Site	DATE	Q	pH	Al	Cd	Cu	Fe	Mn	Pb	Zn	Zn Load	times	2.4451
American Tunnel	CC19	2/17/10	0.178	5.19	5.180	0.0022	0.0057	148.0	49.5	0.0014	19.9			kg/d
American Tunnel	CC19	3/18/10	0.204	4.46	4.810	0.0023	0.0083	145.0	50.3	0.0018	20.6			
American Tunnel	CC19	4/13/10	0.204	5.38	4.710	0.0025	0.0062	159.0	49.7	0.0020	18.4			
American Tunnel	CC19	6/2/10	0.240	5.29	4.200	0.0022	0.0050	136.0	44.5	0.0022	17.6			
American Tunnel	CC19	7/13/10	0.240	5.26	4.590	0.0022	0.0050	157.0	49.9	0.0025	19.7			
American Tunnel	CC19	9/14/10	0.268	4.47	4.930	0.0020	0.0020	164.0	51.4	0.0025	20.4			
American Tunnel	CC19	11/2/10	0.240	5.17	4.660	0.0025	0.0020	142.0	49.1	0.0015	21.4			
Low		**3/18/10**	**0.204**	4.46	4.810	0.0023	0.0083	145.0	50.3	0.0018	20.6	**10.3**		
Median		**Median**	**0.240**	5.19	4.710	0.0022	0.0050	148.0	49.7	0.0020	19.9	**11.7**		
High		**6/2/10**	**0.240**	5.29	4.200	0.0022	0.0050	136.0	44.5	0.0022	17.6	**10.3**		

Prop from AT			cfs	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Name	Site	DATE	Q	pH	Al	Cd	Cu	Fe	Mn	Pb	Zn	
Gold King 7 level	CC06	3/18/10	0.292	4.96	7.670	0.0359	2.6200	52.3	26.5	0.0010	15.5	
Gold King 7 level	CC06	4/14/10	0.333	5.13	7.220	0.0410	2.6900	47.4	26.2	0.0005	13.0	
Gold King 7 level	CC06	6/2/10	0.558	2.82	57.700	0.1330	12.1000	213.0	27.1	0.0207	39.3	
Gold King 7 level	CC06	7/14/10	0.485	3.03	29.800	0.0632	4.9700	81.9	29.6	0.0189	22.5	
Gold King 7 level	CC06	9/14/10	0.449	3.52	25.700	0.0569	5.5400	75.2	31.7	0.0211	21.7	
Gold King 7 level	CC06	11/3/10	0.473	4.13	17.300	0.0533	3.9000	65.8	30.7	0.0065	20.7	
Low		**3/18/10**	**0.292**	4.96	7.670	0.0359	2.6200	52.3	26.5	0.0010	15.5	**11.1**
Median		**Median**	**0.461**	3.83	21.500	0.0551	4.4350	70.5	28.4	0.0127	21.2	**23.9**
High		**6/2/10**	**0.558**	2.82	57.700	0.1330	12.1000	213.0	27.1	0.0207	39.3	**53.6**

Prop from AT on 6/2			cfs	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Name	**Site**	**Date**	Q	pH	Al	Cd	Cu	Fe	Mn	Pb	Zn	
Red & Bonita@c	RBM	02/18/10	0.364	5.44	3.920	0.0381	0.0418	83.1	35.2	0.0043	16.9	
Red & Bonita@c	RBM	03/18/10	0.415	5.76	2.690	0.0365	0.0112	85.6	32.9	0.0587	15.5	
Red & Bonita@c	RBM	04/14/10	0.403	5.94	2.280	0.0409	0.0138	87.1	32.5	0.0021	14.2	
Red & Bonita@c	RBM	06/02/10	0.488	5.94	2.770	0.0386	0.0107	83.1	31.7	0.0089	14.7	
Red & Bonita@c	RBM	07/13/10	0.516	5.89	2.140	0.0372	0.0050	81.9	32.4	0.0107	14.7	
Red & Bonita@c	RBM	09/14/10	0.541	6.14	2.970	0.0341	0.0136	81.1	35.7	0.0062	16.5	
Red & Bonita@c	RBM	11/02/10	0.459	6.46	2.000	0.0380	0.0020	92.7	34.1	0.0079	17.2	
Low		**3/18/10**	**0.415**	5.76	2.690	0.0365	0.0112	85.6	32.9	0.0587	15.5	**15.7**
Median		**Median**	**0.459**	5.94	2.690	0.0380	0.0112	83.1	32.9	0.0079	15.5	**17.4**
High		**6/2/10**	**0.488**	5.94	2.770	0.0386	0.0107	83.1	31.7	0.0089	14.7	**17.5**

Prop from C48 on 6/2			cfs	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Name	**Site**	**Date**	Q	pH	Al	Cd	Cu	Fe	Mn	Pb	Zn	
NF Cement@rd c	CC07A	2/18/10	0.277	3.24	14.300	0.0472	2.8800	38.4	25.9	0.0016	15.6	
NF Cement@rd c	CC07A	3/18/10	0.315	3.16	13.500	0.0451	2.7200	33.5	25.3	0.0016	14.8	
NF Cement@rd c	CC07A	4/14/10	0.608	3.27	14.700	0.0433	2.7900	42.0	21.8	0.0018	11.8	
NF Cement@rd c	CC07A	6/2/10	3.150	3.17	9.160	0.0252	1.6900	19.7	4.4	0.0168	5.7	
NF Cement@rd c	CC07A	7/13/10	0.348	2.99	22.900	0.0516	3.5000	39.1	19.5	0.0137	15.1	
NF Cement@rd c	CC07A	9/14/10	0.295	2.97	28.200	0.0581	4.5800	51.8	28.7	0.0161	21.0	
NF Cement@rd c	CC07A	11/2/10	0.204	3.05	22.300	0.0604	3.6900	47.3	27.1	0.0061	18.7	
Low		**3/18/10**	**0.315**	3.16	13.500	0.0451	2.7200	33.5	25.3	0.0016	14.8	**11.4**
Median		**Median**	**0.315**	3.16	14.700	0.0472	2.8800	39.1	25.3	0.0061	15.1	**11.6**
High		**6/2/10**	**3.150**	3.17	9.160	0.0252	1.6900	19.7	4.4	0.0168	5.7	**43.9**

random in range			cfs	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Name	**Site**	**Date**	Q	pH	Al	Cd	Cu	Fe	Mn	Pb	Zn	
Mogul	CC02D	2/18/10	0.154	3.54	2.910	0.0435	0.0162	30.8	31.1	0.1890	31.2	
Mogul	CC02D	3/18/10	0.162	3.36	2.610	0.0393	0.0183	27.5	29.1	0.1820	28.5	
Mogul	CC02D	4/14/10	0.125	3.38	2.510	0.0410	0.0199	27.4	29.1	0.1780	25.8	
Mogul	CC02D	6/3/10	0.138	3.58	2.390	0.0389	0.0223	22.0	24.1	0.1530	22.9	
Mogul	CC02D	7/14/10	0.095	3.48	3.110	0.0563	0.0322	26.0	28.5	0.1860	29.8	
Mogul	CC02D	9/15/10	0.109	3.48	3.700	0.0557	0.0220	30.2	33.1	0.2190	36.7	
Mogul	CC02D	11/4/10	0.102	3.38	3.230	0.0542	0.0145	29.6	32.9	0.2380	37.8	
Low		**3/18/10**	**0.162**	3.36	2.610	0.0393	0.0183	27.5	29.1	0.1820	28.5	**11.3**
Median		**Median**	**0.125**	3.48	2.910	0.0435	0.0199	27.5	29.1	0.1860	29.8	**9.1**
High		**6/3/10**	**0.138**	3.58	2.390	0.0389	0.0223	22.0	24.1	0.1530	22.9	**7.7**

M34	CFS	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Q	pH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
2/17/2010		4.97	109.0	8.87	5.35	0.50	324	500	4.410	0.0011	0.0103	2.49	0.63	0.0015	0.328
3/2/2010		4.64	95.0	7.87	4.53	0.77			4.172	0.0011	0.0134	2.65	0.66	0.0034	0.241
3/17/2010	17.9	5.02	109.0	8.59	5.67	0.50	307	520	4.700	0.0010	0.0112	2.47	0.63	0.0020	0.292
4/6/2010		4.51	91.2	7.36	4.64	0.93			3.333	0.0010	0.0140	3.35	0.55	0.0045	0.280
4/13/2010	72.8	6.22	53.3	4.11	4.77	0.50	153		0.160	0.0020	0.0123	1.70	0.32	0.0017	0.499
5/5/2010	130.0	6.22	44.2	3.37	2.89	0.50	115	160	0.028	0.0007	0.0040	1.63	1.37	0.0010	0.211
6/2/2010	576.0	7.40	20.1	1.77	1.24	0.31	35	91	0.109	0.0001	0.0046	0.21	0.14	0.0005	0.060
7/8/2010	109.0	6.60	37.0	3.56	1.73	0.44	99	153	0.021	0.0004	0.0022	0.75	0.18	0.0026	0.090
7/13/2010	85.0	6.77	39.5	3.57	2.20	0.50	105	170	0.050	0.0004	0.0050	1.17	0.21	0.0005	0.102
8/10/2010		7.74	41.9	3.73	1.59	0.44			0.041	0.0005	0.0058	1.56	0.24		0.113
9/14/2010	38.0	6.73	70.0	5.94	3.44	0.09	180	280	0.013	0.0007	0.0020	3.17	0.44	0.0001	0.196
10/4/2010		6.30	66.5	5.55	2.89	0.65			0.108	0.0004	0.0050	3.03	0.41		0.161
11/2/2010	33.0	6.40	75.0	6.17	4.02	0.09	202	305	0.013	0.0008	0.0020	3.82	0.45	0.0001	0.233
11/3/2010	38.0	6.45	62.7	4.99	2.94	0.55	187	230	0.049	0.0007	0.0045	3.03	0.37	0.0005	0.202
12/7/2010	51.0	6.48	64.7	5.33	3.62	0.77			0.627	0.0008	0.0086	2.75	0.38	0.0015	0.231

	CFS	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Q	pH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
Min	17.9	4.51	20.1	1.77	1.24	0.09	35	91	0.013	0.0001	0.0020	0.215	0.14	0.0001	0.060
10%	31.5	4.77	38.0	3.45	1.65	0.18	93	141	0.016	0.0004	0.0021	0.918	0.19	0.0002	0.095
15%	34.8	4.98	39.7	3.56	1.78	0.32	101	154	0.021	0.0004	0.0023	1.204	0.21	0.0004	0.103
25%	38.0	5.62	43.0	3.65	2.54	0.44	108	160	0.034	0.0004	0.0042	1.592	0.28	0.0005	0.137
Median	61.9	6.40	64.7	5.33	3.44	0.50	167	230	0.108	0.0007	0.0050	2.490	0.41	0.0015	0.211
75%	103.0	6.67	83.1	6.76	4.58	0.60	198	305	1.980	0.0010	0.0108	3.026	0.59	0.0020	0.261
85%	122.7	6.77	94.7	7.82	4.76	0.76	270	461	4.088	0.0011	0.0122	3.156	0.63	0.0027	0.291
90%	174.6	7.15	103.4	8.30	5.12	0.77	309	504	4.315	0.0011	0.0130	3.280	0.65	0.0032	0.314
Max	576.0	7.74	109.0	8.87	5.67	0.93	324	520	4.700	0.0020	0.0140	3.815	1.37	0.0045	0.499
Avg	115.1	6.16	65.3	5.39	3.43	0.50	171	268	1.189	0.0008	0.0070	2.251	0.47	0.0015	0.216
StDev	165.9	0.96	26.9	2.10	1.39	0.23	91	153	1.877	0.0004	0.0043	1.034	0.30	0.0013	0.111
cv	1.44	0.16	0.41	0.39	0.40	0.46	0.53	0.57	1.58	0.57	0.61	0.46	0.65	0.87	0.51
IQR	65.0	1.05	40.0	3.12	2.04	0.16	91	145	1.946	0.0006	0.0065	1.435	0.31	0.0015	0.124

Low Flow	Q	pH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
3/17/2010	17.9	5.02	109.0	8.59	5.67	0.50	307	520	4.700	0.0010	0.0112	2.470	0.63	0.0020	0.292
Medians															
Median	61.9	6.40	64.7	5.33	3.44	#NUM!	167	230	0.108	0.0007	0.0050	2.490	0.41	0.0015	0.211
4/13/2010	72.8	6.22	53.3	4.11	4.77	0.50	153	250	0.160	0.0020	0.0123	1.700	0.32	0.0017	0.499
12/7/2010	51.0	6.48	64.7	5.33	3.62	0.77	200	300	0.627	0.0008	0.0086	2.752	0.38	0.0015	0.231
Max Flow															
6/2/2010	576.0	7.40	20.1	1.77	1.24	0.31	35	91	0.109	0.0001	0.0046	0.215	0.14	0.0005	0.060

Average of multiple splits
Value = 1/2 LOD
Hot-deck imputation form rest of chemistry where no values available

Zn Loads	**kg/d ***	**lb/d**
Low Q	12.8	28.1
Median Q	31.9	70.1
Max Q	84.7	186.4

cfs *mg/L					
times	2.4451	kg/d			
		times	2.20	5.38	lb/d

	Q	pH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
Q	1														
pH	0.616319	1													
Ca	-0.67193	-0.85163	1												
Mg	-0.69052	-0.83667	0.994932	1											
Na	-0.62505	-0.83443	0.897382	0.863644	1										
K	-0.13787	-0.54742	0.287711	0.276122	0.257532	1									
SO4	-0.70786	-0.90942	0.994511	0.987226	0.900559	0.099568	1								
TDS	-0.58738	-0.91322	0.987069	0.984984	0.975034	0.082296	0.980084	1							
Al	-0.21124	-0.87126	0.846248	0.843342	0.750592	0.442737	0.831064	0.896682	1						
Cd	-0.4805	-0.53749	0.491691	0.44521	0.785137	0.21879	0.477303	0.889273	0.384087	1					
Cu	-0.14666	-0.74526	0.597442	0.56924	0.700064	0.708358	0.529342	0.760212	0.763813	0.675908	1				
Fe	-0.68998	-0.47257	0.710451	0.70386	0.605427	0.112019	0.676854	0.580212	0.273531	0.311712	0.178835	1			
Mn	-0.22471	-0.47134	0.348099	0.298747	0.392897	0.171535	0.266818	0.21701	0.313943	0.251652	0.168923	0.243074	1		
Pb	-0.15923	-0.76137	0.416395	0.425686	0.391564	0.782104	0.208841	0.285486	0.625129	0.332615	0.741274	0.09743	0.130981	1	
Zn	-0.46608	-0.56648	0.560446	0.505434	0.84158	0.209279	0.568377	0.897408	0.410057	0.975224	0.660199	0.396896	0.297538	0.270629	1

A72	CFS	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
DATE	Q	pH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
2/17/2010		5.07	127.0	8.50	5.11	1.23	366	570	3.290	0.0026	0.036	3.25	2.71	0.0027	1.11
3/17/2010	51.6	5.04	122.0	7.81	4.98	1.025	329	545	2.730	0.0027	0.035	2.50	2.90	0.0013	1.20
4/13/2010	138	6.09	63.2	4.51	4.135	0.5	184		0.201	0.0029	0.019	1.94	1.75		0.85
5/4/2010	189	6.56	57.0	3.73	2.53	0.634	155		0.025	0.0018	0.008	1.56	1.13	0.0001	0.60
6/2/2010	1580	6.51	19.1	1.53	1.31	0.5	42	97		0.0007		0.22	0.24		0.21
6/9/2010	1300	7.07	21.0	1.63	1.04	0.452	42		0.062	0.0007	0.003	0.12	0.27	0.0009	0.16
7/8/2010	259	6.8	44.2	3.07	752	0.774	117	188	0.023	0.0010	0.010	0.31	0.66	0.0047	0.36
7/13/2010	205	6.565	48.7	3.58	2.18	0.5	95	220		0.0012	0.007	0.50	0.65		0.35
8/10/2010	199	7.135	49.3	1855.85	1.8035	0.631	140		0.030	0.0014	0.006	0.50	0.95		0.44
9/14/2010	96	6.48	81.0	5.84	3.31	0.6375	196	180		0.0018	0.013	1.54	1.48		0.72
10/4/2010		7.54	75.6	5.09	2.78	0.871			0.148	0.0016	0.014	1.50	1.45		0.63
11/2/2010	99	6.25	83.1	5.63	3.63	0.085	228	345	0.192	0.0021	0.014	2.16	1.68		0.75
11/3/2010	110	6.38	74.4	4.99	2.95	0.6755	219	301	1.089	0.0016	0.010	1.58	1.35		0.58
12/7/2010		5.82	98.5	5.79	3.82	1.201			0.551	0.0020	0.021	2.04	1.83		0.67

	FLOW_CFS	pH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
Min	51.6	5.04	19.1	1.53	1.04	0.09	42	97	0.023	0.0007	0.0031	0.125	0.24	0.0001	0.164
10%	96	5.30	27.9	2.06	1.46	0.47	48	155	0.025	0.0008	0.0060	0.251	0.38	0.0004	0.250
15%	97.5	5.78	43.0	3.00	1.78	0.50	76	180	0.028	0.0010	0.0067	0.310	0.63	0.0006	0.344
25%	104.5	6.13	48.8	3.62	2.27	0.50	111	186	0.046	0.0012	0.0076	0.503	0.73	0.0009	0.375
Median	189	6.50	68.8	5.04	3.13	0.64	169	261	0.192	0.0017	0.0130	1.546	1.40	0.0013	0.613
75%	232	6.74	82.5	5.82	4.06	0.85	221	395	0.820	0.0020	0.0190	2.010	1.73	0.0027	0.743
85%	779.5	7.07	99.7	7.84	4.99	1.03	263	535	1.910	0.0026	0.0236	2.172	1.87	0.0035	0.863
90%	1300	7.12	115.0	8.29	5.07	1.15	319	553	2.730	0.0026	0.0323	2.397	2.45	0.0039	1.032
Max	1580	7.54	127.0	1855.85	752.00	1.23	366	570	3.290	0.0029	0.0359	3.250	2.90	0.0047	1.200
Avg	384.2	6.38	68.9	136.97	56.54	0.69	176	306	0.758	0.0017	0.0151	1.408	1.36	0.0019	0.616
StDev	529.1	0.71	32.6	494.73	200.17	0.31	101	173	1.164	0.0007	0.0104	0.951	0.80	0.0018	0.306
cv	1.4	0.11	0.5	3.61	3.54	0.45	0.57	0.57	1.53	0.40	0.69	0.68	0.59	0.93	0.50
IQR	127.50	0.61	33.68	2.21	1.79	0.35	109.75	209.00	0.77	0.00	0.01	1.51	1.00	0.0018	0.37

Low Flow															
3/17/2010	51.6	5.04	122.0	7.81	4.98	1.03	329	545	2.730	0.0027	0.035	2.50	2.90	0.0013	1.20
Medians															
Median	189	6.50	68.8	5.04	3.13	0.64	169	261	0.192	0.0017	0.0130	1.546	1.40	0.0013	0.613
5/4/2010	189	6.56	57.0	3.73	2.53	0.634	155		0.025	0.0018	0.008	1.56	1.13	0.0001	0.597
Max Flow															
6/2/2010	1580	6.51	19.1	1.53	1.31	0.5	42	97	0.025	0.0007	0.004	0.22	0.24	0.0002	0.21

Average of multiple splits
Value = 1/2 LOD
Hot-deck imputation form rest of chemistry where no values available

Zn Loads	kg/d *	lb/d			
Low Q	151.4	333.1			
Median Q	283.3	623.2			
Max Q	795.8	1750.8			
	cfs *mg/L				
	times	2.4451	kg/d		
			times	2.20	5.38 lb/d

	Q	pH	Ca	Mg	Na	K	SO4	TDS	Al	Cd	Cu	Fe	Mn	Pb	Zn
Q	1														
pH	0.353226	1													
Ca	-0.74232	-0.74706	1												
Mg	-0.11868	0.302743	-0.16864	1											
Na	-0.08228	0.165128	-0.21181	-0.07966	1										
K	-0.22302	-0.47045	0.622847	-0.05629	0.077642	1									
SO4	-0.7418	-0.86593	0.98823	-0.10859	-0.17807	0.594174	1								
TDS	-0.58504	-0.9359	0.930885	0.907722	-0.27082	0.596797	0.94233	1							
Al	-0.31698	-0.82909	0.829437	-0.20457	-0.20564	0.619263	0.887271	0.935047	1						
Cd	-0.68636	-0.70384	0.817119	-0.11451	-0.27752	0.351619	0.850998	0.923141	0.582242	1					
Cu	-0.46657	-0.8698	0.916711	-0.26845	-0.1346	0.64692	0.915721	0.939708	0.880169	0.810555	1				
Fe	-0.64747	-0.7592	0.931135	-0.26959	-0.32517	0.467841	0.947176	0.908963	0.736967	0.904976	0.864631	1			
Mn	-0.6681	-0.78373	0.96704	-0.14468	-0.24487	0.563093	0.974239	0.944901	0.827123	0.91209	0.95206	0.948015	1		
Pb	-0.18695	-0.00257	0.037913	0.061582	0.85409	0.34624	0.059386	-0.88672	0.05954	-0.15864	0.137595	-0.13089	-0.03896	1	
Zn	-0.67692	-0.77169	0.93009	-0.16613	-0.23921	0.477819	0.954164	0.922737	0.790191	0.943651	0.922477	0.942436	0.985702	-0.06678	1

FLOW AND MASS-LOAD SUMMARY - RIVER STTAIONS AND ADITS

River Stations

CFS	Low Flow	Median	High Flow
	3/17/2010	Calculated	6/2/2010
A68	18.9	58	517
C48	13.70	19.00	137.00
M34	17.9	61.9	576
A72 Observed	51.6	189	1580

Adits

CFS	Low Flow	Median	High Flow
	3/17/2010	Calculated	6/2/2010
AT	0.204	0.240	0.240
GC	0.292	0.461	0.558
RB	0.415	0.459	0.488
Mogul	0.162	0.125	0.138
C48 Obs.	13.7	19	137

kg Zn /d	Low Flow	Median	High Flow
	3/17/2010	Calculated	6/2/2010
A68	28.2	57.8	347.4
C48	87.1	110.2	222.4
M34	12.8	31.9	84.7
A72 Observed	151.4	283.3	795.8

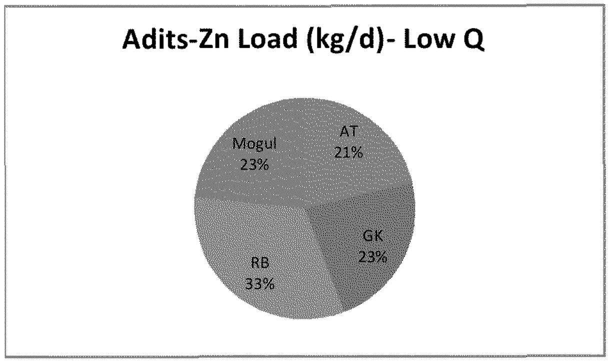
kg Zn /d	Low Flow	Median	High Flow
	3/17/2010	Calculated	6/2/2010
AT	10.28	11.68	10.33
GC	11.07	23.90	53.62
RB	15.73	17.38	17.52
Mogul	11.29	9.11	7.73
C48 Obs.	87.10	110.18	222.41

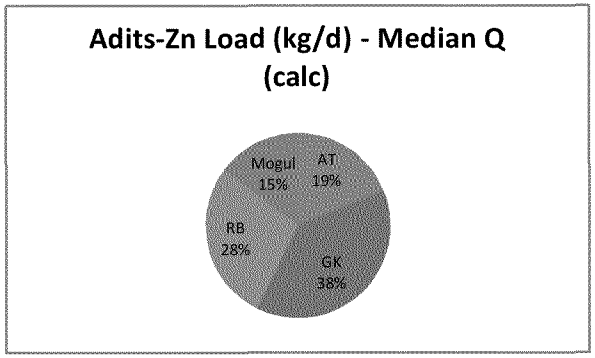
Flow and Zn Balance - Adits

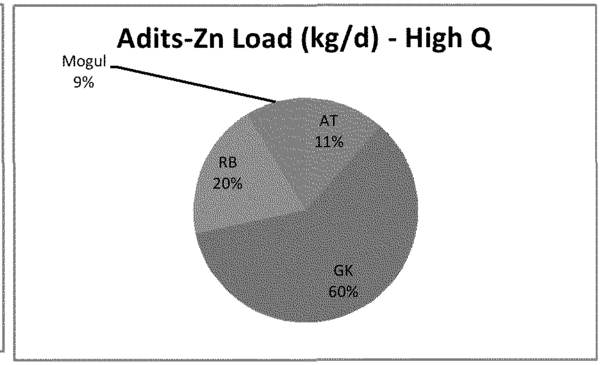
Adits

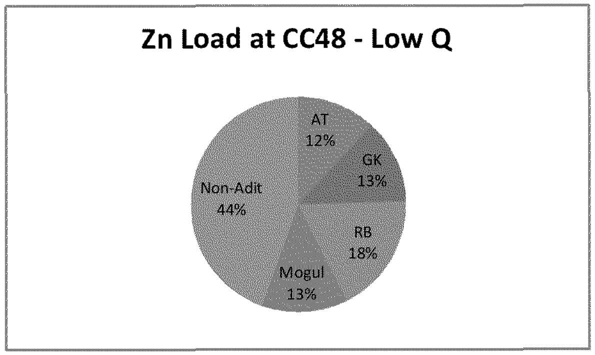
CFS	Low Flow	Median	High Flow
	3/17/2010	Calculated	6/2/2010
AT	0.204	0.240	0.240
GC	0.292	0.461	0.558
RB	0.415	0.459	0.488
Mogul	0.162	0.125	0.138
Total	**1.073**	**1.285**	**1.424**
C48 Obs.	13.7	19	137
prop of C48	7.8%	6.8%	1.0%

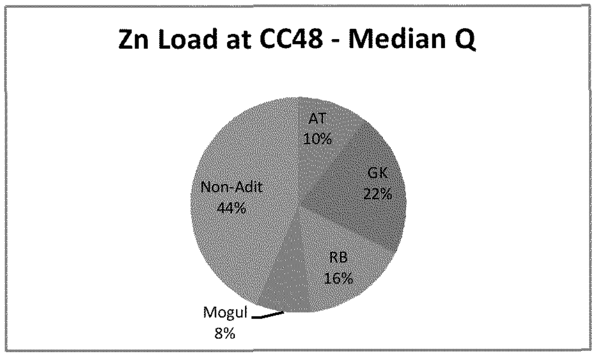
kg Zn /d	Low Flow	Median	High Flow
	3/17/2010	Calculated	6/2/2010
AT	10.28	11.68	10.33
GK	11.07	23.90	53.62
RB	15.73	17.38	17.52
Mogul	11.29	9.11	7.73
Non-Adit	38.74	48.11	133.21
Total	**48.36**	**62.06**	**89.20**
C48 Obs.	87.10	110.18	222.41
prop of C48	55.5%	56.3%	40.1%

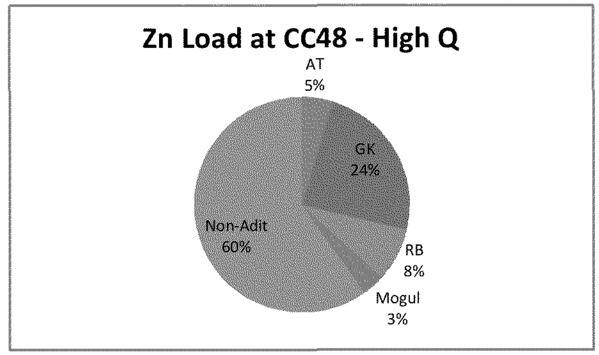

Adits-Zn Load (kg/d)- Low Q
Mogul 23%
AT 21%
GK 23%
RB 33%


Adits-Zn Load (kg/d) - Median Q (calc)
Mogul 15%
AT 19%
RB 28%
GK 38%


Adits-Zn Load (kg/d) - High Q
Mogul 9%
AT 11%
RB 20%
GK 60%

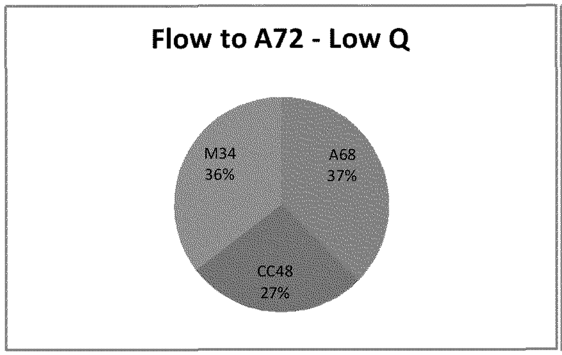

Zn Load at CC48 - Low Q
AT 12%
GK 13%
Non-Adit 44%
RB 18%
Mogul 13%

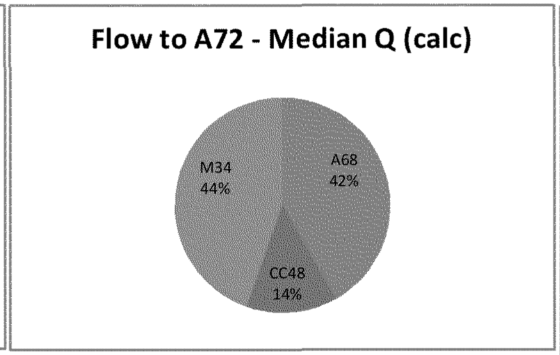

Zn Load at CC48 - Median Q
AT 10%
GK 22%
Non-Adit 44%
RB 16%
Mogul 8%

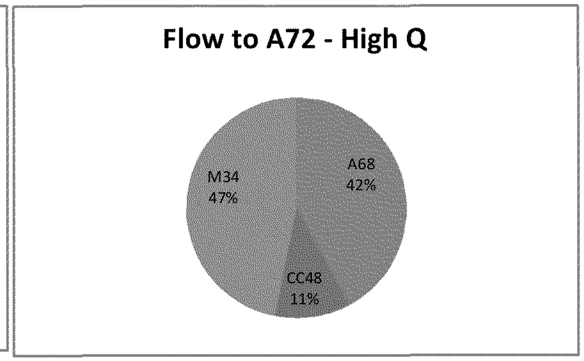

Zn Load at CC48 - High Q
AT 5%
GK 24%
Non-Adit 60%
RB 8%
Mogul 3%

FLOW BALANCE CALCULATIONS AT A72

CFS	Low Flow 3/17/2010		Median Calculated		High Flow 6/2/2010	
A68	18.9	37%	58	42%	517	42%
CC48	13.70	27%	19.00	14%	137.00	11%
M34	17.9	35%	61.9	45%	576	47%
Total	50.5		138.9		1230	
A72 Observed	51.6		189		1580	
RPD (A72 obs - Total) / (A72 obs + Total)	1.1%		15.3%		12.5%	

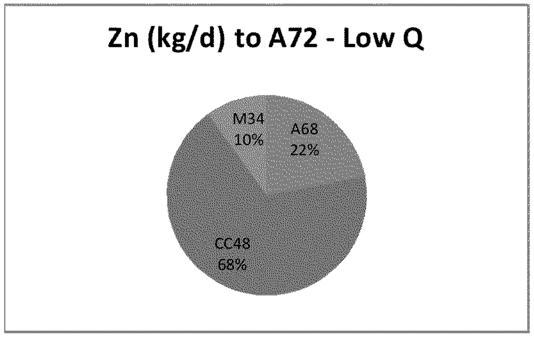


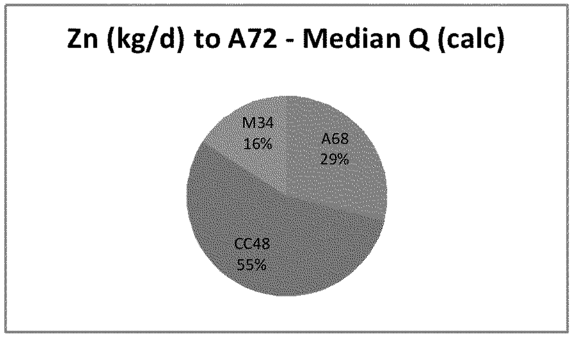


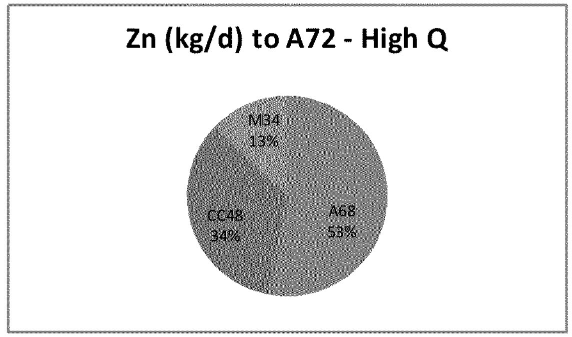


Zn-BALANCE CALCULATIONS AT A72

kg Zn /d	Low Flow		Median		High Flow	
	3/17/2010		Calculated		6/2/2010	
A68	28.2	22%	57.8	29%	347.4	53%
CC48	87.1	68%	110.2	55%	222.4	34%
M34	12.8	10%	31.9	16%	84.7	13%
Total	128.1		199.8		654.6	
A72 Observed	151.4		283.3		795.8	
RPD (A72 obs - Total) / (A72 obs + Total)	8.4%		17.3%		9.7%	







CALCULATED CONCENTRATIONS AT A72 WITH MASS REMOVAL AT ADITS

Calculates apparent concentration of Zn (mg/L) at A72 for % removal of Mass loading a Adits

Let **Jzn** (X) be the Load of Zn in kg/d at the point X in th eparenthesis

∑Q be the sum of the Adit flows for the condition tested in CFS

% rem be the percent removal of adit mass load

Mzn be the calculated concentration of Zn in mg/L

	Zn	Low Q		Median Q		High Q	
		3/17/2010		**Calc**		**6/2/2010**	
Observed	Jzn(A72)	151.4	kg/d	283.3	kg/d	795.8377	kg/d
Observed	Jzn(Adits)	48.4	kg/d	62.1	kg/d	89.20	kg/d
	%rem	1		1		1	
	Δ Jzn	103.0	kg/d	221.2	kg/d	706.6	kg/d
Observed	Q(A72)	51.6	cfs	189	cfs	1580	cfs
	Factor	2.44512	FIXED	2.44512	FIXED	2.44512	FIXED
	Mzn	0.817	mg/L	0.479	mg/L	0.183	mg/L
	Mzn	816.7	ug/L	478.7	ug/L	182.9	ug/L
Observed	Mzn(obs)	1.20	mg/L	0.613	mg/L	0.206	mg/L

Variable Treatment Factor - Modeler sets

SUMMARY AND EVALUATION

Flow: Range of balance 1.1% RPD for low Q to 15.3% RPD for Calculated Median (12.5% at High Q)

Good to Reasonable for Flow

Mass: Range of balance from 8.4% for Low Q to 17.3% for Calculated Median (9.7% for High Q)

Good to Reasonable for Mass.

Flow from Adits is a minor component of Q at C48 (1%-6%)

Zn Load from Adits is a large component of Zn load at C48 (40% to 56%)

Removal fo Zn Load from Adits is Important to Observed Zn concentration at A72 for Low Q, somewhat for Median Q, but a minor difference for High Q. See Note below on high variance for calculated Median

Note: For general considerations assume Q values are precise to ~+/- 20%; chemical values to ~+/- 10%. Most of the variance in Load is associated with Q.

Note: All RPD Show Observed Q and Mass > Calculated. Looks to be systematic to higher measured Q values at A72

Note: **Highest variance is for <u>calculated</u> Median**. Note that each value is calculated as median separately - no covariance structure included.